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**DESIGN & DEVELOPMENT  
of a  
FAMILY OF DRY-TYPE AIR CLEANERS**

Final Technical Report

by  
T.G. Donnelly

Protective Systems Department  
Research & Development Division  
DONALDSON COMPANY, INC.  
Minneapolis, Minnesota

Under  
CONTRACT DA-11-022-AMC-2041(T)

JUL 31 1967

April 1966

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Prepared for  
UNITED STATES ARMY TANK-AUTOMOTIVE CENTER  
WARREN, MICHIGAN

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⑥ DESIGN & DEVELOPMENT  
of a  
FAMILY OF DRY-TYPE AIR CLEANERS,

④ Final Technical Report,

⑩ by T. G. Donnelly

3 Protective Systems Department  
Research & Development Division  
DONALDSON COMPANY, INC.  
2 Minneapolis, Minnesota

(115885)

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⑪ Apr 1966

⑫ 33p.

Prepared for  
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### ABSTRACT

This contract covered design and development of a family of dry-type engine air cleaners ranging from 110 to 800 cfm capacity for wheeled and light-tracked vehicles. Basic considerations included designing the family to (1) withstand the extreme environments encountered in military use, (2) adequately protect vehicle engine and, (3) provide installation versatility to allow widespread use.

The resulting family of air cleaners use interchangeable air manifolds and dust cups, allowing 18 variations on 6 basic models. Laboratory tests confirmed that the performance meets the requirements of MIL-E-76736(MO).

A family of air cleaners is now available for wheeled and light-tracked vehicles and should be used wherever possible on new engine air cleaner installations to better standardize military air cleaners.

Written by T.G. Donnelly  
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DEPARTMENT OF THE ARMY  
UNITED STATES ARMY TANK-AUTOMOTIVE COMMAND  
WARREN, MICHIGAN 48090

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SUBJECT: Design and Development of a Family of Dry-  
Type Air Cleaners.

Date: April 1966


Contract No.: DA-11-022-AMC-2041 (T)

Contractor: Donaldson Company Inc.  
Minneapolis, Minnesota

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FOR THE COMMANDER:

  
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## I INTRODUCTION

This report summarizes effort performed under Contract DA-11-022-AMC-2041(T) to design, develop and fabricate prototype models of a family of dry-type air cleaners for wheeled and light-tracked vehicles. Effort began 11 March 1965 and continued over a 12 month period.

## II BACKGROUND

Modern military strategy stresses mobility of not only heavy armored combat vehicles but also lightly armored tracked vehicles and wheeled vehicles. Performance and logistic requirements of military ground vehicles have taken on added importance to meet this need. Advancements in materials and manufacturing techniques allows higher machine speeds, closer tolerances and higher stress loads. Complex mechanisms are often needed to provide the desired level of vehicle performance. Along with these advancements, the problems associated with vehicle maintenance and reliability have necessarily increased.

Diverse types of vehicles are necessary to achieve the mobility requirements in a wide range of terrain and climatic conditions. This creates a significant logistics problem to properly maintain the vehicles. One method of combating the logistics problem is standardization of similar types of vehicle parts or components whenever possible. Proper design of vehicle components for maximum reliability and durability decreases the need for frequent maintenance. Reducing the number of models, standardizing parts, eliminating special tools, and minimizing the skills necessary for maintenance will decrease the time necessary to service the vehicles.

In 1959 a family of dry-type air cleaners for heavy tracked vehicles was developed. The air cleaners developed under Contract DA-11-022-AMC-2041(T) compliment these air cleaners by providing a family of dry-type air cleaners for wheeled and light-tracked vehicles. This provides the military with two complimentary standard lines of air cleaners covering engine airflow requirements up to 900 cfm.

These lines do not duplicate each other, however. The family of air cleaners developed in 1959 is rectangular in cross-section and is based on service life of 20 hours operation to an air restriction of 15 inches water gage (wg) under zero visibility dust concentration (0.025 gm/cu ft air). These air cleaners are designed for use with a dust exhaust blower operating on a 24 volt DC electrical system.

The new family of cleaners for wheeled and light-tracked vehicles is round in cross-section and is based on a service life of 20 hours operation to an air restriction of 20 inch

wg. The new family of cleaners does not require a dust removal blower and may be used on vehicles, regardless of the type of electrical systems. However, provision for use of a dust exhaust blower is provided on the three larger sizes; 410, 550, and 800 cfm.

The air cleaners are designed to provide maximum engine protection while requiring minimum maintenance. Laboratory performance, structural, and environmental tests indicate that these air cleaners should perform satisfactorily in field use. The following section presents the design and performance criteria which formed the basis for the resulting air cleaner configurations.

### III DESIGN AND PERFORMANCE CRITERIA

Specific design and performance requirements include the following:

- The six air cleaners should range in airflow from approximately 110 cfm to 800 cfm.
- The minimum service life shall be 20 hr without exceeding 20 inch wg restriction.
- Efficiency shall not be less than 99 percent.
- The filter media shall be flame resistant.
- The element shall withstand a backfire pressure of 100 psig.
- The element shall be cleanable such that after initial cleaning following initial dust loading, restriction must be within 1-inch wg from original value.
- The element shall be capable of withstanding 24 hr of vibration with the frequency varying between 10 and 55 cps with an amplitude of 0.03 in. (0.06 in. maximum excursion). The frequency range shall be swept 10 cps to 55 cps and back to 10 cps in one minute.
- The air cleaner shall be capable of operation in either horizontal or vertical attitudes.
- The air cleaner shall be capable of operation over a temperature range of +125°F to -65°F.

The air cleaner shall not leak when subjected to a vacuum of 50 inch wg when functional openings of the air cleaner are sealed.

Superimposed on these specific design requirements were the following general requirements:

- Prepare layout drawings for a family of six dry-type air cleaners.
- Fabricate and test one or more prototypes to confirm the design.
- Test the family of six air cleaners.

- Furnish one complete set of Class I Military drawings.
- Furnish a Designers Handbook to facilitate application of the air cleaners.

These general and specific design requirements, while restrictive enough to insure that the resulting air cleaner line would have the necessary characteristics for military use, allowed for a variety of approaches to this air cleaner line. The basic design approaches which were examined are summarized in the following section.

#### IV DESIGN APPROACH

##### A ALTERNATIVES CONSIDERED

The initial proposal for this contract work, as well as the Statement of Work, suggested that rectangular air cleaner configurations were desirable. However, in that cylindrical shapes offer many advantages over rectangular shapes such as easier mounting, flexibility of inlet/outlet locations and lower fabrication costs, both rectangular and cylindrical configurations were considered.

The design study portion of the contractual effort was broken into three phases: selection of types of dust separators, selection of filter media and selection of the basic air cleaner configuration.

##### 1 Dust Separators

The potential dust separators included louvers, cyclonic separator tubes, and fin arrangements. The use of louvers was not actively pursued since either cyclonic tube or fin arrangements give equal or superior efficiency within the same size package.

Cyclonic separator tubes are available in two different configurations. One is a reverse flow cyclone tube, approximately 1.5 in. diameter by 6.5 in. long. This tube is presently used in the heavy duty rectangular air cleaner line. The other separator tube type is axial-flow centrifugal device. This tube is also used in current military and civilian applications. Axial-flow separator tubes, however, require scavenging flow to maintain a reasonably high efficiency. Scavenging flow can most practically be obtained by use of electric motor driven exhaust blowers or aspirators (ejectors). It was decided that any scavenging flow option should utilize the standard Ordnance No. 1095010 Exhaust Blower. (This blower is currently used on the M60 heavy-duty rectangular engine air cleaner.) In that the proposed line of air cleaners may be used on vehicles not having sufficient electrical power to operate an exhaust blower or may not have any other convenient means of producing scavenging airflow, use of separator tubes requiring scavenging flow was not considered further. Thus, use of cyclone tubes was limited to the reverse-flow type.

Fin arrangements are used in various ways on different air cleaners. Basically, however, a series of fins is placed near the top of the air cleaner and directs incoming dusty air in a spiral motion, thereby centrifugally separating out the large dust particles. Both the fin arrangements and reverse-flow cyclone separator tubes were carried through further design analysis.

## 2 Filter Media

Two different types of synthetic fiber filter media were candidates for inclusion in the new family. One was needle-punched Dacron felt, Ordinance No. 1083995. The other was a new synthetic material having equivalent resistance to environmental conditions, but having distinct advantages in efficiency and thickness.

## 3 Air Cleaner Configuration

### a. Selection of Basic Style

Two basic air cleaner configurations were considered: cylindrical and rectangular. Within the cylindrical configuration, use of both the reverse-flow and fin-type dust separation was analyzed on both qualitative and quantitative bases. The more significant factors affecting the ultimate choice are discussed below.

Regardless of external configuration, an air cleaner will require space on a vehicle for mounting. The space allowed for the air cleaner will in all probability be defined by imaginary rectangular boundaries. A rectangular cleaner would be able to use this space most efficiently, in that a round cleaner configuration would not fill in the corners of a rectangular space allotted for the cleaner. However, this unused space could be utilized for various hoses or lines.

Rectangular cleaners do have some installation problems. For example, one has the choice of only two directions for inlet and outlet. These either are at right angles or parallel to one another. It is also necessary to have separate housing tooling, depending on whether one prefers the openings on one side or the other. Rectangular air cleaners also have a problem of difficult gasketing. Long flat sections are generally more difficult to seal than cylindrical shapes.

Cylindrical designs have definite advantages in mounting flexibility. The inlet and/or outlet locations are easily varied by rotating the air cleaner. Also, by using mounting bands, attachment of a cylindrical air cleaner to a vehicle is accomplished more easily than a rectangular air cleaner. It is only necessary to permanently attach the mounting band to the vehicle with bolts. Then, the air cleaner can be slipped within the

band and the band tightened down. This differs from the rectangular configuration in that the latter would almost always require a direct threaded attachment to the air cleaner as well as to the vehicle.

In order to obtain a quantitative method of analyzing these different configurations, the various sizes, weights and costs of each configuration were estimated based on known operating characteristics of each style of air cleaner. This analysis indicated that in each case the cylindrical cleaner with the fin-type dust separator had a lower estimated weight, smaller volume per cfm and lower relative cost. The advantages were more pronounced in the smaller sizes. In the larger sizes, the basis of evaluation showed the three different styles of cleaners were approximately the same. This was primarily the result of the higher efficiency of the cyclonic dust separator tubes. Also, the rectangular configuration became more attractive in the larger sizes because it made more efficient use of its volume. In cylindrical cleaners, a greater amount of space was lost in the center of the element in the larger sizes.

The rectangular style cleaner was handicapped in this evaluation by the modular construction requirement. In order to keep the external surfaces of the air cleaner relatively clean as mounting surfaces, the means of joining the modular sections (the element housing and the dust separator section) had to be internal. This required a considerable amount of space, adding materially to the overall length of the cleaners.

A numerical rating system was established to objectively determine the best configuration for the family of air cleaners. This system, which is commonly used in cases where analysis must consider many factors, attempted to define the most important design parameters and to assign weighted ratings to each parameter. Each of the designs were comparatively rated according to the rating of an optimum unit. The totals of the various ratings showed a significant advantage in the fin-type approach. Thus, the fin-type two-stage air cleaners were recommended and subsequently approved as the design approach for the new family of air cleaners. (Refer to Monthly Report No. 3 for the detailed discussion of design approach justification)

#### b. Air Inlet/Outlet Locations

Experience had shown the desirability of having the option of either top inlet or side inlet engine air cleaners. Versatility was of prime importance for this family of air cleaners because of the potentially wide variety of installations upon which the family will be used. Because of the added versatility obtained by having the option of selecting inlet/outlet configuration, it was decided that the family should be designed for use with either a side inlet or a top inlet air manifold.

The fin-type of air cleaner, because of its centrifugal dust separator configuration, requires that the clean air side of the element is always in the center of the element. It follows that the dirty air side is then the outside of the element.

The side inlet/top outlet manifold configuration is the more compact arrangement. This type of manifold draws the dirty air into the side of the cylindrical housing and it flows around the outside of the element. The outlet, located over the center of the filter element, simply ducts the clean air out the end of the cylindrical body.

The top inlet/side outlet configuration requires a more complex ducting arrangement. In this case the air is ducted down and around the outlet duct which extends from the top of the filter element and then turns 90 degrees to exit through the side of the cylindrical housing. The more complex ducting on the latter design requires more vertical length to the air cleaner.

#### c. Minimum Dust Cup Drop

The majority of fin-type air cleaners in existence today contain a dust cup which is relatively shallow compared to the total length of the air cleaner. That is, the clamp holding the dust cup to the housing is located relatively near the bottom of the air cleaner. To remove the filter element for replacing or cleaning, one must first remove the dust cup and then unfasten the filter element from within the housing. Sufficient room must be available below the air cleaner to allow the element to be removed from the housing. For example, an element 12 in. long could potentially require a space below the air cleaner of at least 12 in. length which is free from any other obstruction. It was desirable to keep the required space for element removal to a minimum, along with the actual physical size of the air cleaner.

Minimum air cleaner length can be achieved by inserting the filter element as far as possible into the air manifold. Carried to an extreme, minimum air cleaner length would be only slightly greater than the length of the filter element plus a minimum depth for the dust cup. This approach, however, would necessitate an appreciable distance available to remove the filter element and dust cup. The element must drop below the joint between the air manifold and the dust cup. In order to use band clamps for mounting the air cleaner to the vehicle, sufficient room must be available below the inlet duct for a band clamp. Thus, the minimum height of the air manifold was dictated by the required inlet duct diameter, mounting band width and space required by the sealing and clamping arrangement for joining the dust cup to the manifold.



The effective volume required for air cleaner installation includes both room for the physical size of the air cleaner and sufficient clearance for element removal. Whether the air cleaners were designed for either of the extremes noted above, the effective volume required for installation was approximately equal. The resulting configurations were compromises of minimum physical length, minimum dust cup drop and other design parameters such as inlet ducting pressure drop, attachment of the dust separator fin and the air cleaner housing seal design.

A combination of minimum air cleaner length and minimum dust cup drop could have been obtained by substantially increasing the complexity of the design and decreasing reliability. This method would have involved use of an additional joint in the dust cup at an elevation equal to the filter element bottom. Inclusion of such a joint would have allowed the dust cup to be removed for emptying without necessarily removing the element. If element removal were also desired, the upper joint could also have been broken, allowing the element to drop into the space vacated by the removed dust cup. This approach was not recommended, however, due to the increased complexity of fabrication, added cost and increased possibility of leakage.

#### d. Seals

Integrity of both the element seal and the housing seal were of prime importance. The design requirement of minimum dust cup drop for element removal necessitated use of parallel seals. With this approach, both the element and the cleaner housing are sealed simultaneously when the overcenter clamps on the cleaner housing are closed. Use of two straight compression gaskets requires that the clamps have considerable take-up to insure adequate gasket compression in spite of tolerance buildup on the parts of the air cleaner.

It was originally felt that using two different types of gaskets would better provide the needed sealing: a compression seal on the element and a wiper type seal on the cleaner housing. The element seal, being a straight compression type gasket, would receive the full compression force provided by the overcenter clamps used to close the air cleaners. This would be the most positive seal and thereby provide maximum protection for the engine. Use of a wiper seal was attempted on a laboratory fixture. However, adequate sealing was not obtained. Therefore, the compression gasket was also chosen for the manifold/dust cup seal.

#### e. Dust Baffle Design

A modified commercial version of a 250 cfm fin-type air cleaner was used to develop a suitable dust baffle design. The dust baffle functions as a divider between the dust storage area of the dust cup and the filter element. The baffle prevents the separated dust from being recirculated and deposited on the filter element.

Various designs of baffles were tested. Basically, each consisted of a ring extending from the bottom of the filter element to the outside wall of the dust cup. Both flat and conical designs were tested. Of the conical designs, both upward and downward sloping configurations were investigated. Along with the basic baffle design, various types of dust slots and breather holes were tested.

The dust baffle design shown to be most advantageous consisted of a short truncated cone, located at the element bottom and extending downward at an angle to the dust cup wall. A dust skimmer is formed by cutting a rectangular opening in the baffle and bending the metal flap upward. A baffle plate extends vertically between the downstream edge of the dust slot and the dust cup bottom. This prevents excessive swirling of dust from beneath the dust baffle. A series of round breather holes behind the dust slot allows equalization of pressure within the dust cup, below the dust baffle.

#### f. Filter Media Selection

Concurrently with the above analysis, the type of filter media was chosen. The new synthetic media was chosen over the previously used Ordnance Dacron felt. As stated earlier, the new media offered significant advantage in higher efficiency and less thickness. The media is also resistant to flame.

### B PRELIMINARY LABORATORY TESTS

Layout drawings of the family were prepared, based on the design approach discussed above. Upon approval of the layout drawings, three preliminary prototypes were fabricated and tested. These were nominally rated at 250, 410, and 900 cfm.

The 250 and 410 cfm air cleaners, when tested with AC Coarse Test Dust under varying airflows, gave dust capacities of 22.5 and 23 hours, respectively. The 900 cfm air cleaner, when tested with elements of 3 different pleat spacings, reached a maximum of 17.3 hours operation under similar dust capacity testing. In all cases overall efficiency was 99.9 percent or above.

Based on these tests, the 250 and 410 cfm air cleaners were resized when redrawn to Class I format. The resizing was done to bring estimated dust capacity to 20 hours. The 900 cfm air cleaner, however, was left the same size. It was agreed with the Government Technical Supervisor that the unit was already at the maximum realistic size. If after laboratory tests of the final prototype model, the dust capacity was appreciably below 20 hours, the air cleaner would have to be derated in airflow.

Other minor design revisions were shown to be desirable from these preliminary tests. These were incorporated in Class I drawings of the entire family, from which the final prototypes were fabricated. The design and performance of these final prototypes are discussed in the following section.

## V DESIGN AND PERFORMANCE

### A FUNCTIONAL AND PHYSICAL DESCRIPTION

#### 1 General

The family of air cleaners is pictured in Figure 1. The upper photo shows the air cleaners assembled. The lower photo shows a typical air cleaner exploded into its three primary sub-assemblies.

The family of engine air cleaners are two-stage, dry-type air cleaners. The first air cleaning stage is a centrifugal dust separator, consisting of a finned sleeve, located in the upper portion of the air cleaner encircling the dust filter element. The second stage is a cylindrical filter element containing pleated fibrous filter media. Figure 2 is a functional diagram of the basic air cleaner configuration (side air inlet, top air outlet).

Contaminated air is drawn through the inlet of the cleaner and into an annular plenum at the top of the dust filter element. From this plenum, the air passes downward through the separator fins, which cause the air to swirl downward within the body of the cleaner. Dust particles are forced toward the outer surface of the cleaner body and are collected by a skimmer in the dust baffle located at the base of the dust filter element. The collected dust passes through a slot into the dust cup. The partially cleaned air passes through the dust filter element and out of the air cleaner into the engine air induction system.

The centrifugal dust separator removes up to 85 percent of the dust from the incoming air. All of this dust is collected in the space below the dust baffle. The volume of this space is sized so as to require servicing only when the dust filter element required servicing. That is, the air cleaner restriction should reach 20 inch wg, due to filter element dust loading, simultaneously with the time that the dust cup needs servicing.



FIGURE 1. FAMILY OF AIR CLEANERS FOR WHEELED AND LIGHT TRACKED VEHICLES

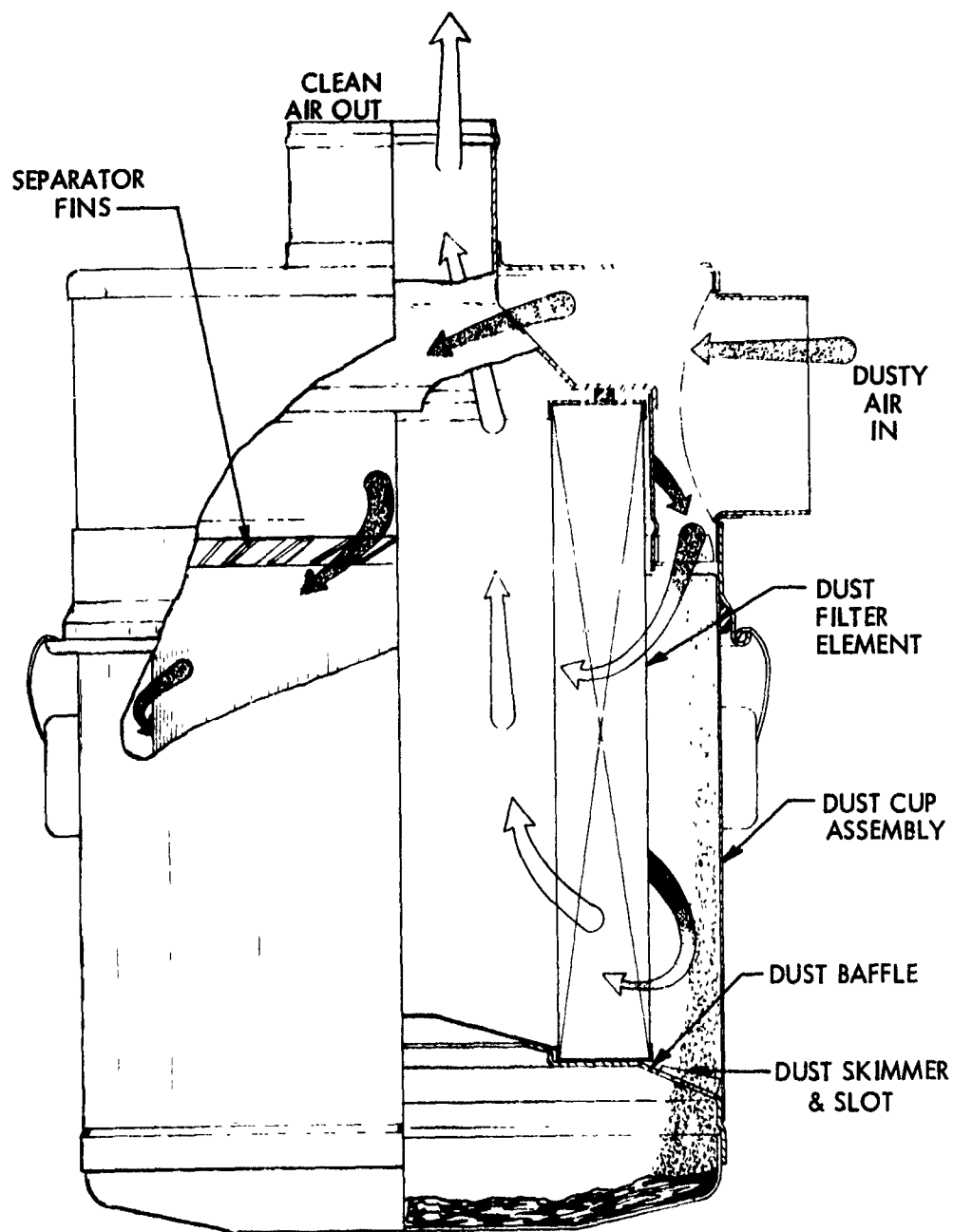


FIGURE 2. FUNCTIONAL DIAGRAM, STANDARD MANIFOLD AND DUST CUP

The first stage of dust separation, by greatly reducing the quantity of dust reaching the dust filter element, results in reduced maintenance and service of the element. The dust filter element contains an extended area of synthetic filter media. This media is resistant to fungus, rot, mildew, and similar environments. The media is formed into pleats to provide the required area within a small volume. The efficiency of the dust filter element is such that the overall air cleaner efficiency is over 99.7 percent on standardized Air Cleaner Fine Test Dust, regardless of airflow rate.

The filter element rests on the cone-shaped dust baffle near the bottom of the dust cup. The filter element is sealed into the air cleaner assembly by compression of its integral gasket against the air manifold. The compressive force is furnished by over-center latches located on the outside of the dust cup. These latches engage a lip around the bottom of the air manifold.

A gasket seals between the dust cup and air manifold. This allows the cleaner to be immersed in water, as in fording operation, without leakage.

This family of air cleaners may be mounted vertically or horizontally. The only requirement for horizontal mounting of the air cleaners is that the slot in the dust baffle must be positioned at the top.

## 2 Design Options

### a. Air Manifolds

This family of engine air cleaners has been designed for maximum flexibility in installation and use. The basic configuration, as shown in Figure 2, consists of a side inlet/top outlet air manifold connected to a closed dust cup. This manifold is referred to as the "standard" style of air manifold.

For installation flexibility, another manifold, with a top inlet/side outlet, can be substituted. The top inlet/side outlet configuration is referred to as the "optional" air manifold. Figure 3 illustrates the optional air manifold (top inlet/side outlet). The function of this configuration is the same as the basic design. The manifolds are interchangeable with the dust cup and element assemblies. The optional manifold increases the overall length of the air cleaner, as well as causing a slight increase in the initial restriction. However, this configuration may be useful in some application.

### b. Dust Cups

In heavy dust concentrations, or where extra-long service life is desired,

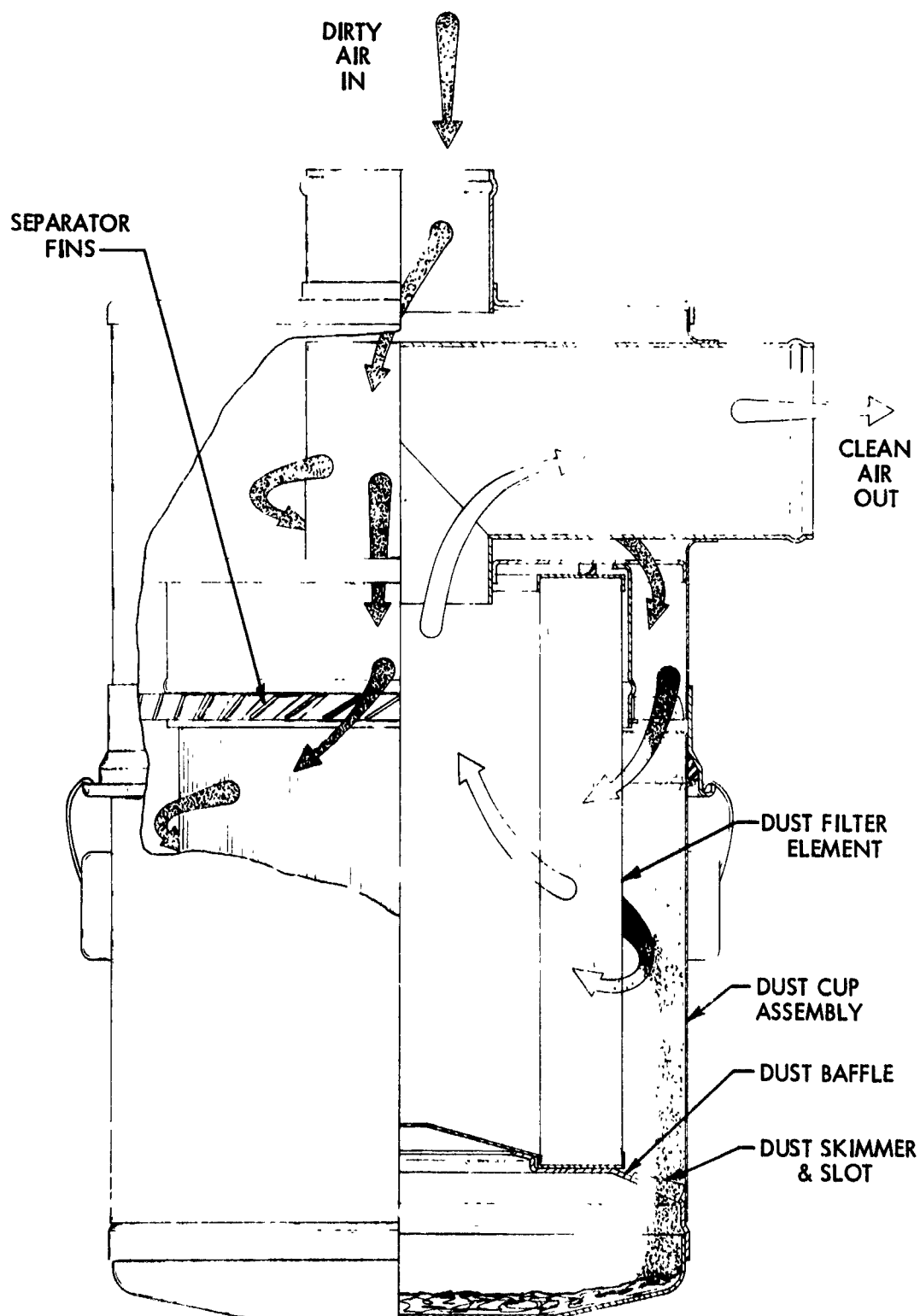


FIGURE 3. FUNCTIONAL DIAGRAM, OPTIONAL MANIFOLD  
(TOP AIR INLET), STANDARD DUST CUP

able, the standard, sealed dust cup may be replaced with a cup connected to an automatic dust exhaust blower. The sealed dust cup is referred to as the "standard" style. The dust cup used with automatic dust exhaustion is referred to as the "dust exhauster" style. The engineering drawings for the family, however, refer to these cups as "dust cup assembly" and "housing assembly", respectively.

The dust exhauster style cup is available in the three larger air cleaner sizes: 410, 550, and 800 cfm. This option results in an air cleaner with a slightly greater service life because of improved efficiency in the first stage, the centrifugal dust separator. The dust exhauster cup provides a tubular connection to the dust baffle slot instead of a sealed dust cup. A means of automatic dust ejection, such as an electrical exhaust blower or exhaust ejector, is connected to the air cleaner dust outlet. Standard Ordnance No. 10905019 exhauster blowers, rated at 41 cfm at 6 inch wg, are available for the purpose. Continuous ejection of dust eliminates the need for a large dust cup or servicing the cup. The element, of course, still requires periodic service. A power source for the exhauster must be available.

### 3 Airflow Ratings

Rated airflow of this family ranges from 110 cfm to 800 cfm in six steps. Table I lists the rated airflows and the part number corresponding to each air cleaner configuration in each size.

TABLE I  
AIR CLEANER RATED AIR FLOWS & ORDNANCE PART NUMBERS

Airflow Rating, cfm	Air Cleaner Configuration			
	Standard Manifold (Side Inlet) with Standard Dust Cup	Optional Manifold (Top Inlet) with Standard Dust Cup	Standard Manifold (Side Inlet) with Dust Exhauster Cup	Optional Manifold (Top Inlet) with Dust Exhauster Cup
110	11604553	11604594	- - - - -	- - - - -
250	11604554	11604595	- - - - -	- - - - -
320	11604555	11604596	- - - - -	- - - - -
410	11604556	11604597	11604600	11604603
550	11604557	11604598	11604601	11604604
800	11604558	11604599	11604602	11604605



#### 4 Air Cleaner Sizes and Weights

Table II tabulates the dimensions and weights of all 18 air cleaner variations. These air cleaners have been designed for minimum volume consistent with the requirement of 20 hours service life to a maximum air restriction of 20 inch wg.

An assembly drawing of the 250 cfm size, standard configuration air cleaner (P/N 11604554) is shown in Figure 4. This drawing is typical of drawings of other sizes.

#### B PERFORMANCE

##### 1 General

There is no existing military specification specifically written for this family of dry-type engine air cleaners. The existing specification used for performance tests was MIL-E-46736(MO), ELEMENT, AIR CLEANER, INTAKE, DRY-TYPE, dated 11 December 1962. Since this specification covers only the dust filter element of an air cleaner, three modifications to its content were made.

First, the crush resistance requirement in par. 3.4.5.1 was disregarded since the dust filter elements of the family use sponge rubber gaskets on metal end caps rather than integral molded plastisol end caps.

Second, the period of time required for restriction to rise to 20 inch wg was changed from 4 hours to 20 hours in par 3.4.4.

Third, an additional requirement was added which called for no air leakage of the air cleaner when subjected to a vacuum of 50 inch wg, or an air pressure of 2 psig when functional openings of the air cleaner are sealed.

The following summarizes the salient requirements of the performance tests. The actual specification contains detailed information.

- Efficiency. Over 99 percent on Air Cleaner Fine Test Dust at rated airflow (par 3.4.3)
- Dust Capacity. 20 hours operation on Air Cleaner Coarse Test Dust at a concentration of 0.025 gm/cu ft under variable airflow (par 3.4.4)
- Restriction After Cleaning. Less than 1-inch wg rise in initial restriction after cleaning subsequent to a dust capacity test (par 3.4.4.1)

TABLE II  
AIR CLEANER DIMENSIONS & WEIGHTS

Air Cleaner Part No.	Air Flow Rating, cfm	Nominal Diameter, inches	Length,* inches	Additional length required for Service of Dust Cup & Element, inches	Weight, lb	Air Inlet Location	Dust Cup Style	Air Inlet/Outlet Tube Diameters, inches
11604553	110	8	12.09	5.88	12.0	Side	Standard	2.5
11604594	110	8	15.38	5.88	16.0	Top	Standard	2.5
11604554	250	10	16.44	7.41	18.3	Side	Standard	3.5
11604595	250	10	21.38	7.41	22.0	Top	Standard	3.5
11604555	320	12	16.41	7.91	27.2	Side	Standard	4.0
11604596	320	12	21.85	7.91	36.7	Top	Standard	4.0
11604556	410	14	16.94	8.44	35.5	Side	Standard	4.5
11604597	410	14	22.88	8.44	46.8	Top	Standard	4.5
11604600	410	14	14.69	8.44	30.9	Side	Dust Exhauster	4.5
11604603	410	14	20.66	8.44	42.2	Top	Dust Exhauster	4.5
11604557	550	16	20.41	8.91	45.5	Side	Standard	5.0
11604598	550	16	26.88	8.91	59.8	Top	Standard	5.0
11604601	550	16	17.25	8.91	39.4	Side	Dust Exhauster	5.0
11604604	550	16	23.67	8.91	53.7	Top	Dust Exhauster	5.0
11604558	800	18	23.25	10.41	60.5	Side	Standard	6.5
11604599	800	18	31.17	10.41	79.5	Top	Standard	6.5
11604602	800	18	19.75	10.41	51.9	Side	Dust Exhauster	6.5
11604605	800	18	27.67	10.41	70.9	Top	Dust Exhauster	6.5

\* Length from bottom of dust cup to top of air manifold, not including the air outlet/inlet tube.



- **Vibration Resistance.** Withstand 24 hours vibration as specified in method 201A of MIL-STD-202 under ambient, 150°F and -65°F temperatures (par 3.4.5.2)
- **Efficiency After Vibration.** Over 99 percent on Air Cleaner Fine Test Dust at rated flow after vibration resistance testing (par 3.4.5.3)
- **Ozone Resistance.** Resistance of all gaskets to ozone (par 3.4.5.4)
- **Durability.** Withstand repeated dust loading and washing (par 3.4.5.5)

Each of these is discussed separately below.

## 2 Efficiency

Air cleaner efficiency was based on the percentage weight of dust removed from the air. Efficiency, as reported here, will be:

$$\text{efficiency} = \frac{\text{weight of dust removed by air cleaner}}{\text{weight of dust entering the air cleaner}} \times 100$$

Military Specification MIL-E-46736(MO) requires a minimum of 99 percent efficiency on Air Cleaner Fine Test Dust.

Efficiency measurements are included on the Performance Test Tabulation, Table III. In all cases, measured efficiency was substantially in excess of the minimum requirements.

## 3 Dust Capacity

The family of air cleaners was designed to permit 20 hours operation at varying airflow with AC Coarse Test Dust under zero visibility dust concentration (0.025 gm/cu ft) before reaching an air restriction of 20 inch wg. As will be subsequently covered, the four smaller size air cleaners met this goal. The two larger air cleaners fell sufficiently below the 20 hour service life at original airflow rating to require derating the air cleaners in terms of airflow.

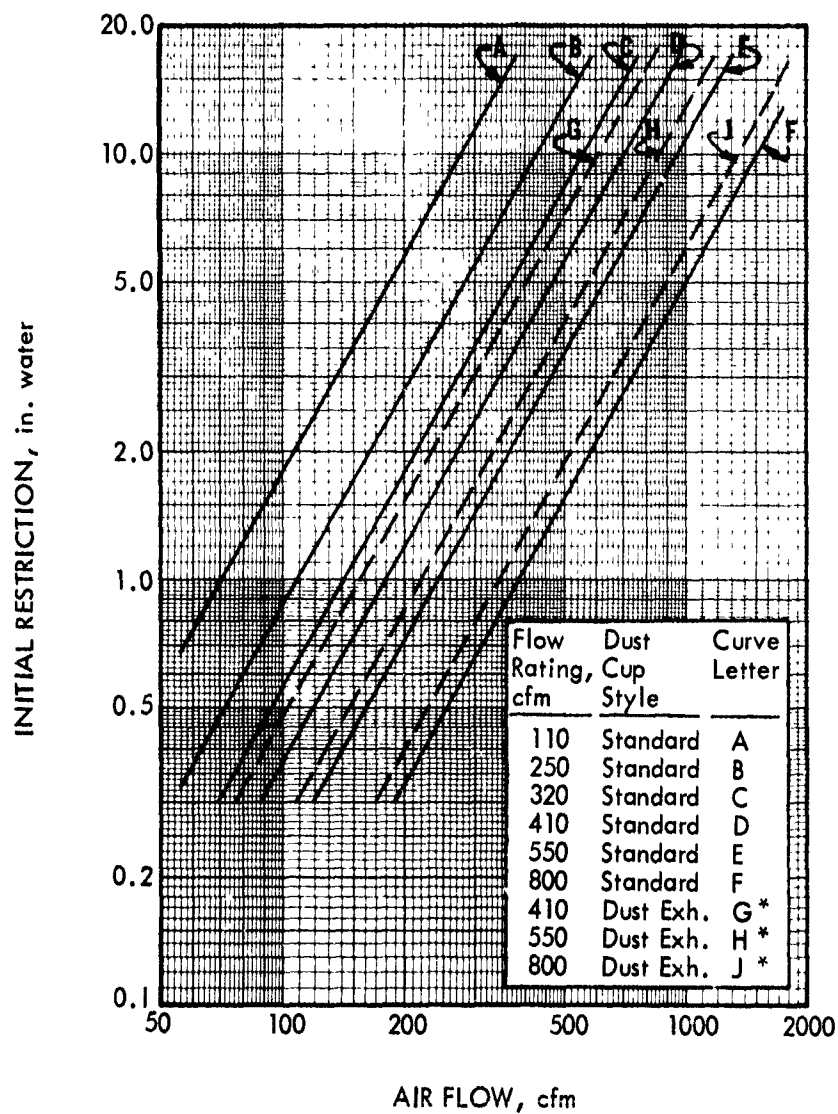
The 20 inch wg total air restriction is not entirely available for dust loading. The clean, initial restriction varies between 2 and 5 inch wg, as shown on Figures 5 and 6.

TABLE III  
PERFORMANCE TEST TABULATION

	Air Cleaner							
	Airflow Rating, cfm Ordinance P/N	110 11604553	250 11604554	320 11604555	410 11604556	615(550)* 11604557	900(800)** 11604558	410 11604600
Initial Restriction, inch wg		2.1	4.1	3.9	4.0	4.8(4.0)	4.4(3.5)	4.9
Restriction After Cleaning, inch wg		2.8	4.8	4.6	4.7	5.5(4.7)	5.1(4.2)	--
Overall Efficiency, on AC Fine Dust, percent		99.95	99.88	99.89	99.79	99.53	99.88	--
Overall Efficiency, on AC Fine Dust, After Vibration, percent		99.94	99.87	99.83	99.54	99.40	99.80	--
Dust Capacity to 20 inch wg, hours		21.3	20.4	19.0	19.2	15.9(20.0)	16.1(20.0)	24.9
Vibration Resistance, damage noted after test		none	none	none	none	none	none	--
Durability, damage noted after test		--	--	none	--	--	--	--
Leakage under 50 in. water vacuum		none	none	none	none	none	none	--
Backfire, damage noted after test		none	none	none	none	none	none	--

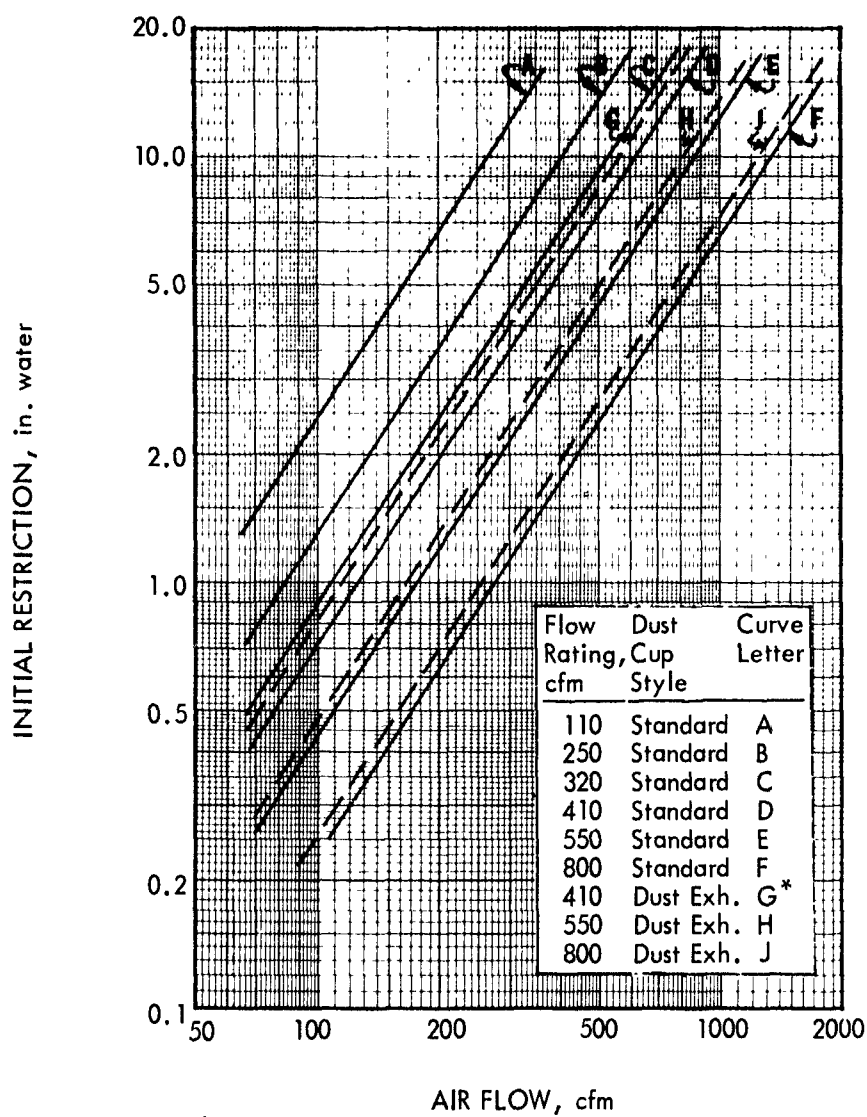
\* Performance tests were run at 615 cfm. Airflow rating was subsequently reduced to 550 cfm, for which extrapolated data is shown in parenthesis.

\*\* Performance tests were run at 900 cfm. Airflow rating was subsequently reduced to 800 cfm, for which extrapolated data is shown in parenthesis.



\* Calculated curves. Curves A-F from actual data.

FIGURE 5. AIR CLEANER INITIAL RESTRICTION CURVES, STANDARD AIR MANIFOLDS



\* Curve G from actual data. Other curves calculated.

FIGURE 6. AIR CLEANER INITIAL RESTRICTION CURVES, OPTIONAL AIR MANIFOLDS

Initial restriction, by itself, provides little information relative to dust capacity (service life) of dry-type air cleaners. That is, a low initial restriction does not necessarily mean a high dust capacity (long service life) nor does a high initial restriction necessarily mean low dust capacity. Dust capacity is a function of not only the initial restriction across the cleaner but also precleaner efficiency, area of the filter element, and the dust loading characteristic of the filter material. However, holding all other variables constant, level of initial restriction does limit the allowable restriction rise.

Dust capacities were obtained, per par 3.4.4. of MIL-E-46736(MO), using an air floated dust feeder. The data obtained are presented graphically on Figures 7 through 13 and tabulated on Table III for the number of hours operation accumulated before reaching 20 inch wg restriction. The graphs also indicate the quantity of dust fed.

The dust capacities of the 110, 225, 320 and 410 cfm air cleaners were 21.3, 20.4, 19.0, and 19.2 hours, respectively. Since these dust capacities were relatively close to the 20 hour goal, the airflow rating of these sizes was left unchanged from the airflow ratings used in the performance tests. Variation in test methods and filter media necessitate some tolerance in dust capacity between different lots of air cleaners.

The two larger air cleaners, originally rated at 615 and 900 cfm, respectively, did not reach the 20 hour life goal. Upon completion of initial tests, new dust filter elements were fabricated, taking special care to improve pleat configuration and evenness of spacing. Two reruns of the 615 cfm size air cleaner with improved filter elements showed only nominal improvement. The one rerun of the 900 cfm air cleaner showed a 3 hour increase in life from 13 to 16 hours.

In that pleat configuration was felt to be as good as could be expected with good fabrication techniques, further work to optimize pleat configuration was not performed. Also, based on characteristics of the media, the amount of media (and corresponding pleat spacing), was felt to be optimum. Since the probability of increasing dust capacity within the given envelope was considered negligible, the dust capacities of each air cleaner were recalculated for lower airflows. The resulting airflows required to increase dust capacity to 20 hours were 550 cfm for the original 615 cfm size and 800 cfm for the original 900 cfm size. This is approximately a 10 percent derating in airflow for each.

The net result of the dust capacity tests and airflow derating is that the family of air cleaners should all operate for nominally 20 hours under the specified laboratory conditions of varying airflow and AC Coarse Test Dust at the rated airflows of 110, 250, 320, 410, 550 and 800 cfm.



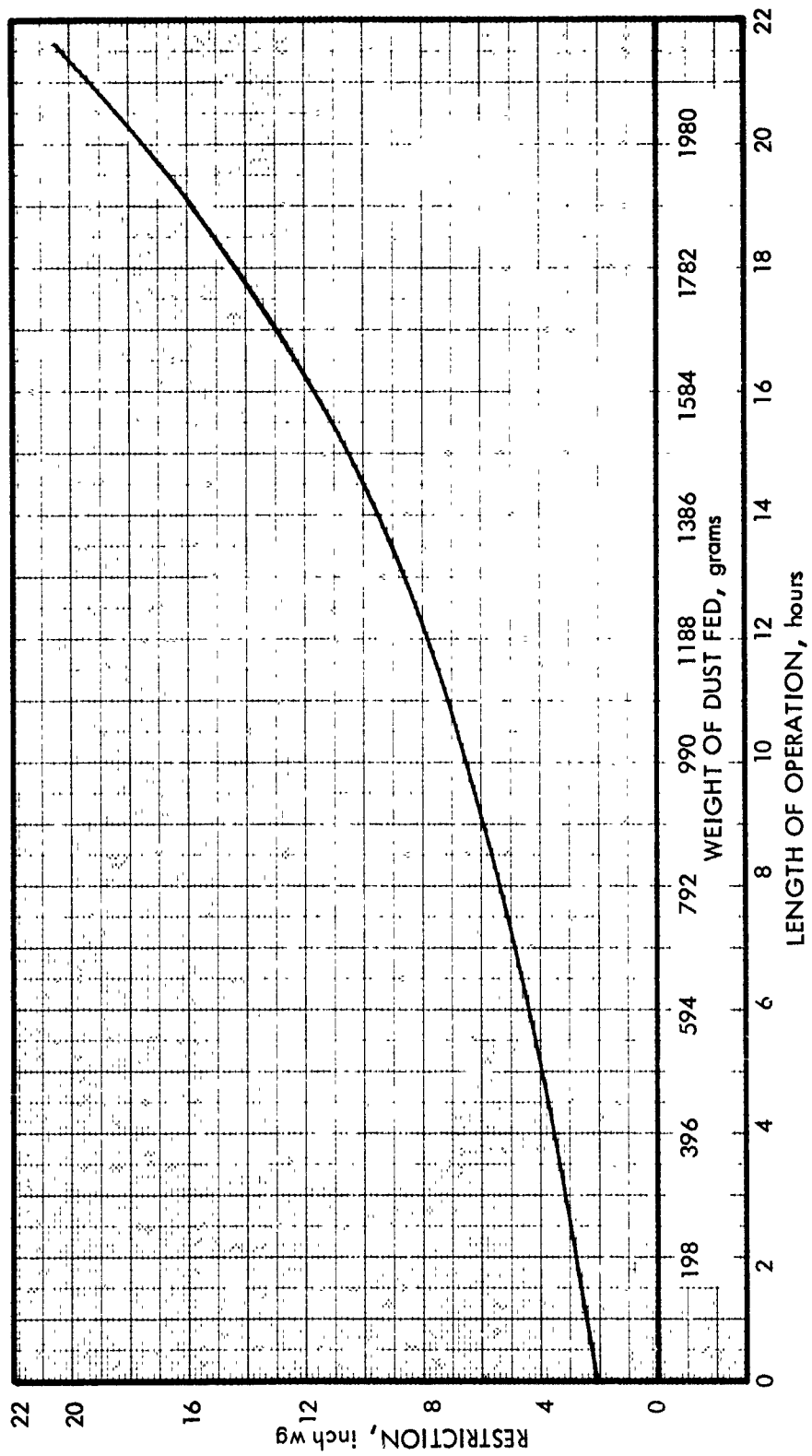


FIGURE 7. 110 CFM PROTOTYPE AIR CLEANER DUST CAPACITY WITH STANDARD MANIFOLD AND DUST CUP

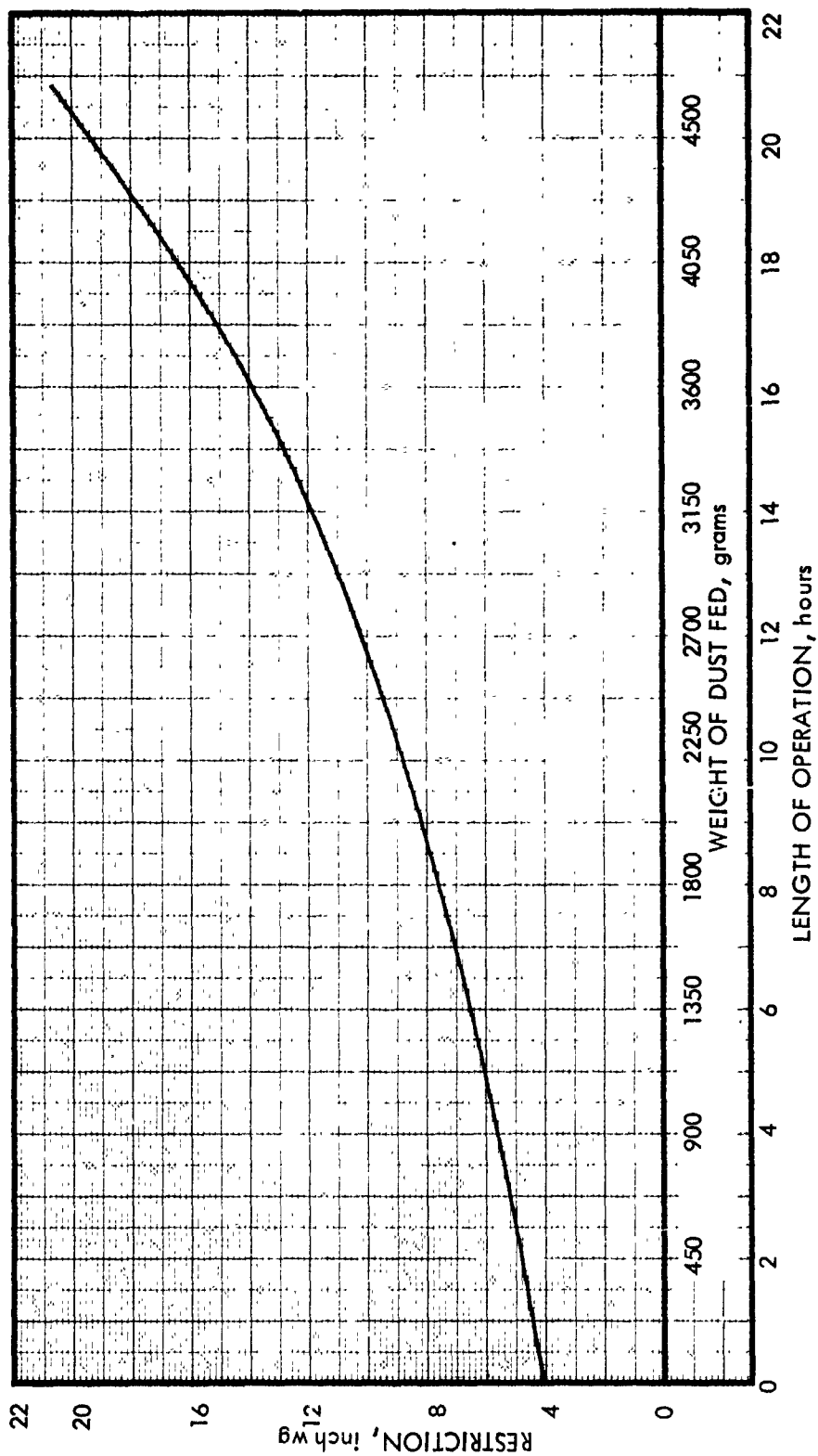


FIGURE 8. 250 CFM PROTOTYPE AIR CLEANER DUST CAPACITY WITH STANDARD MANIFOLD AND DUST CUP

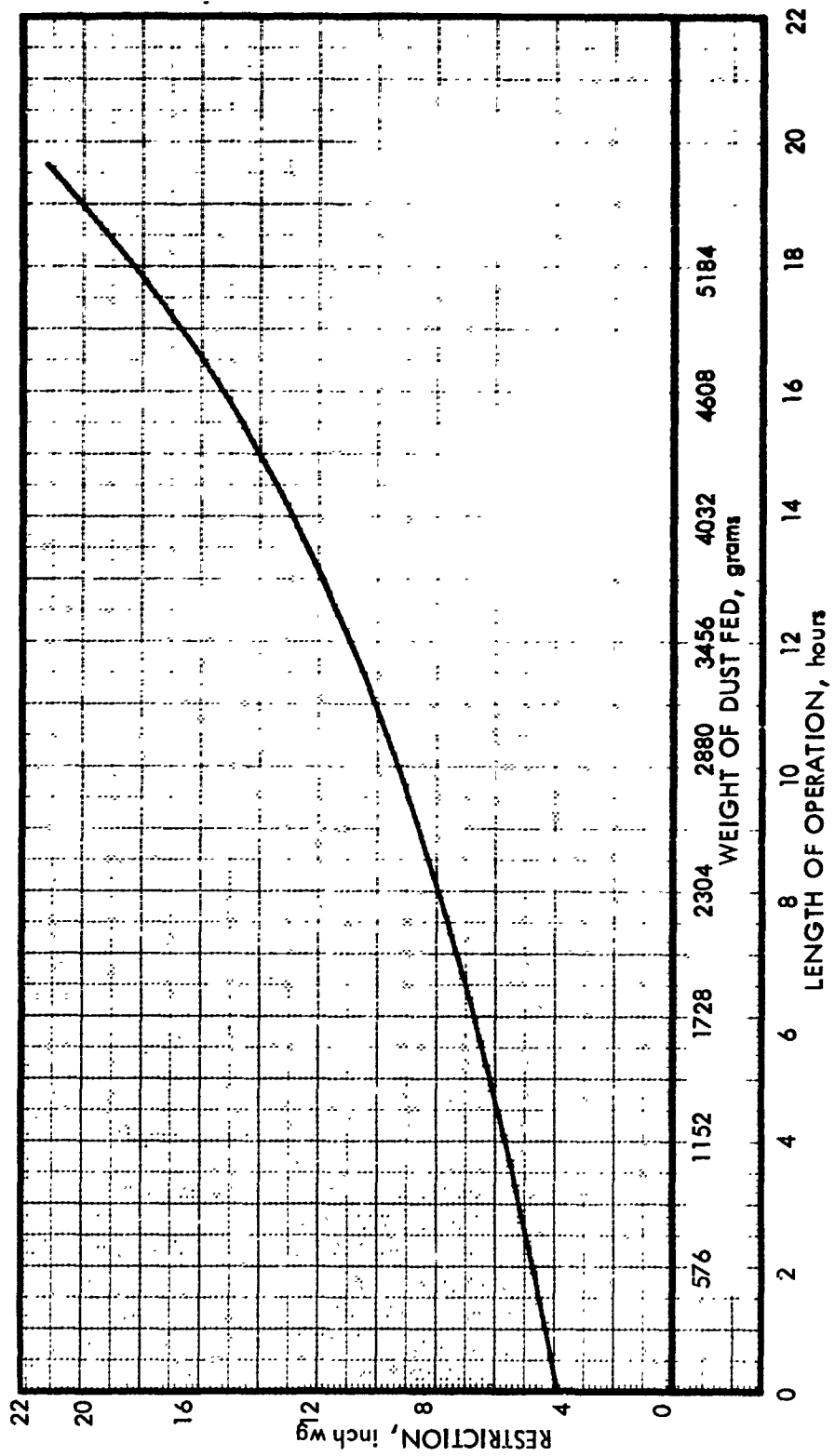


FIGURE 9. 320 CFM PROTOTYPE AIR CLEANER DUST CAPACITY WITH STANDARD MANIFOLD AND DUST CUP

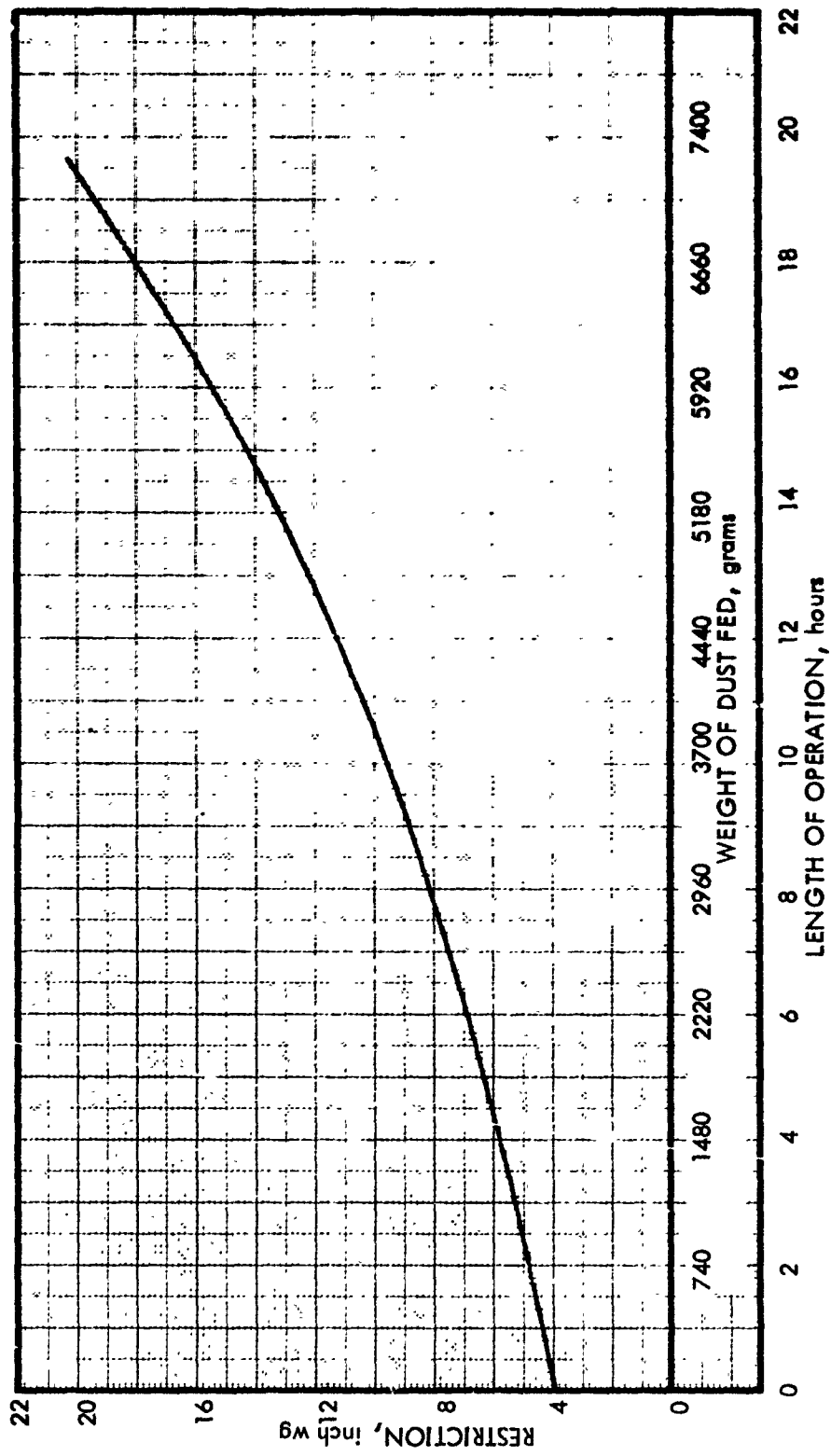


FIGURE 10. 410 CFM PROTOTYPE AIR CLEANER DUST CAPACITY WITH STANDARD MANIFOLD AND DUST CUP

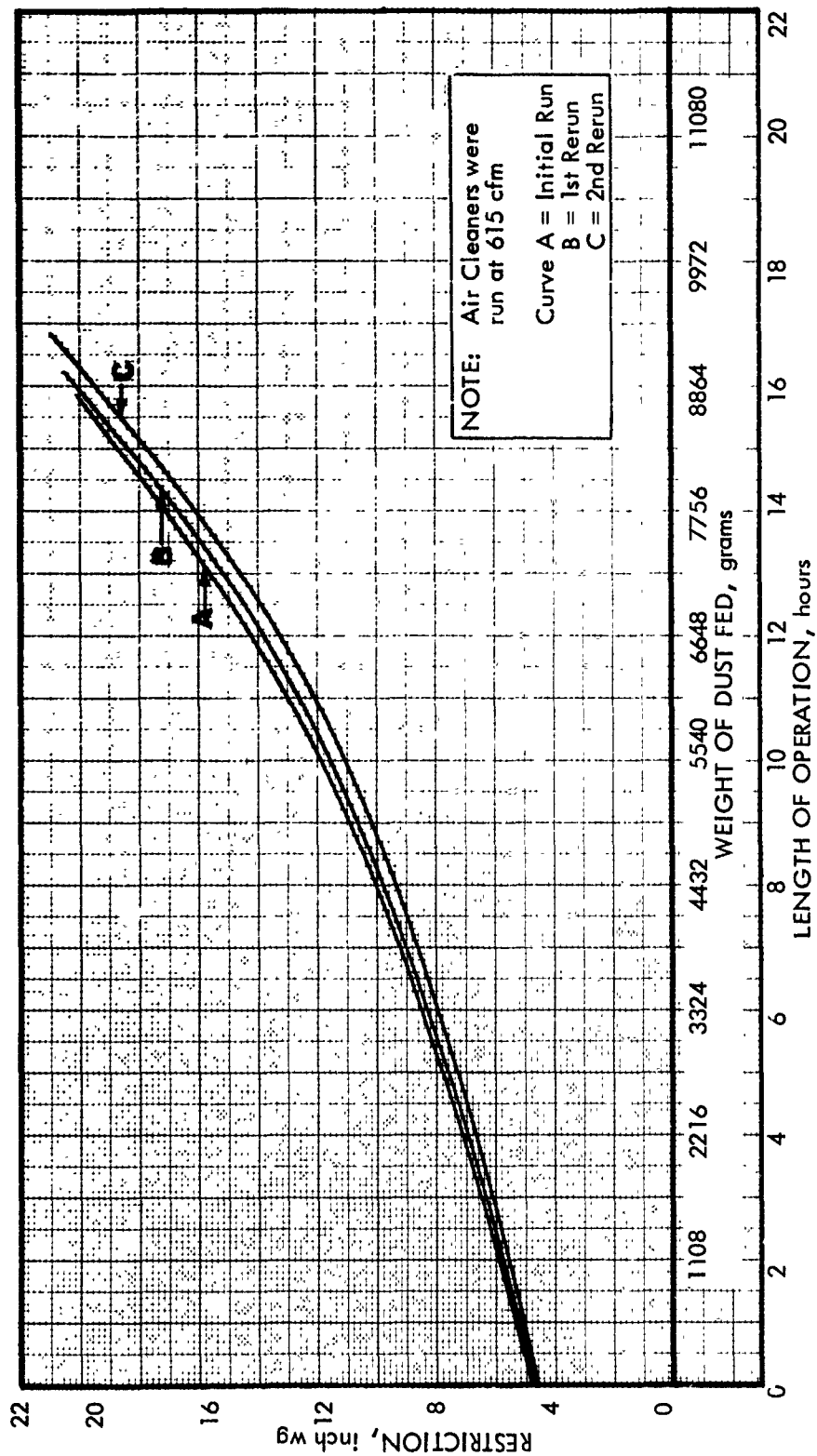


FIGURE 11. 550 CFM PROTOTYPE AIR CLEANER DUST CAPACITY WITH STANDARD MANIFOLD AND DUST CUP

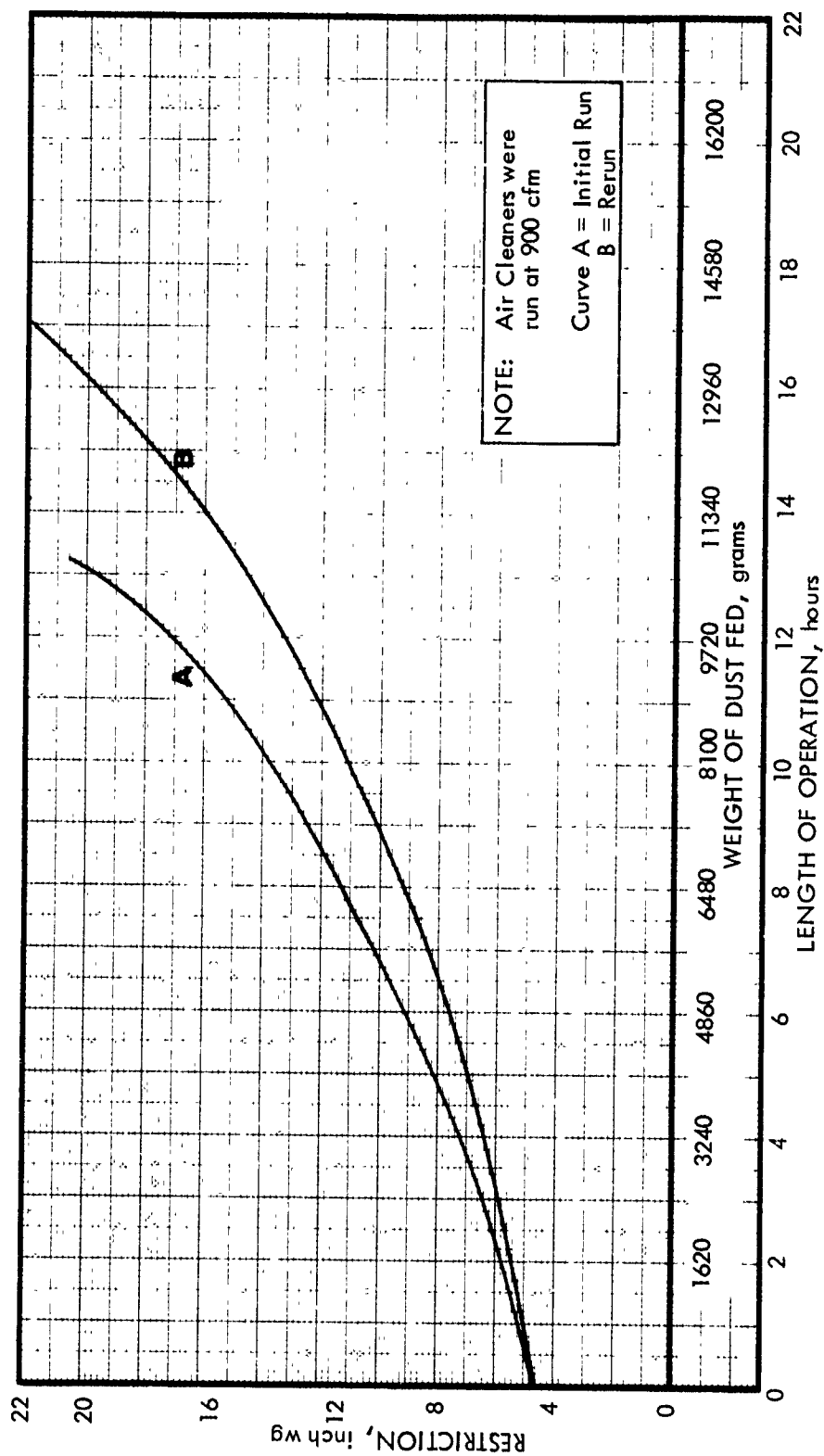


FIGURE 12. 800 CFM PROTOTYPE AIR CLEANER DUST CAPACITY WITH STANDARD MANIFOLD AND DUST CUP

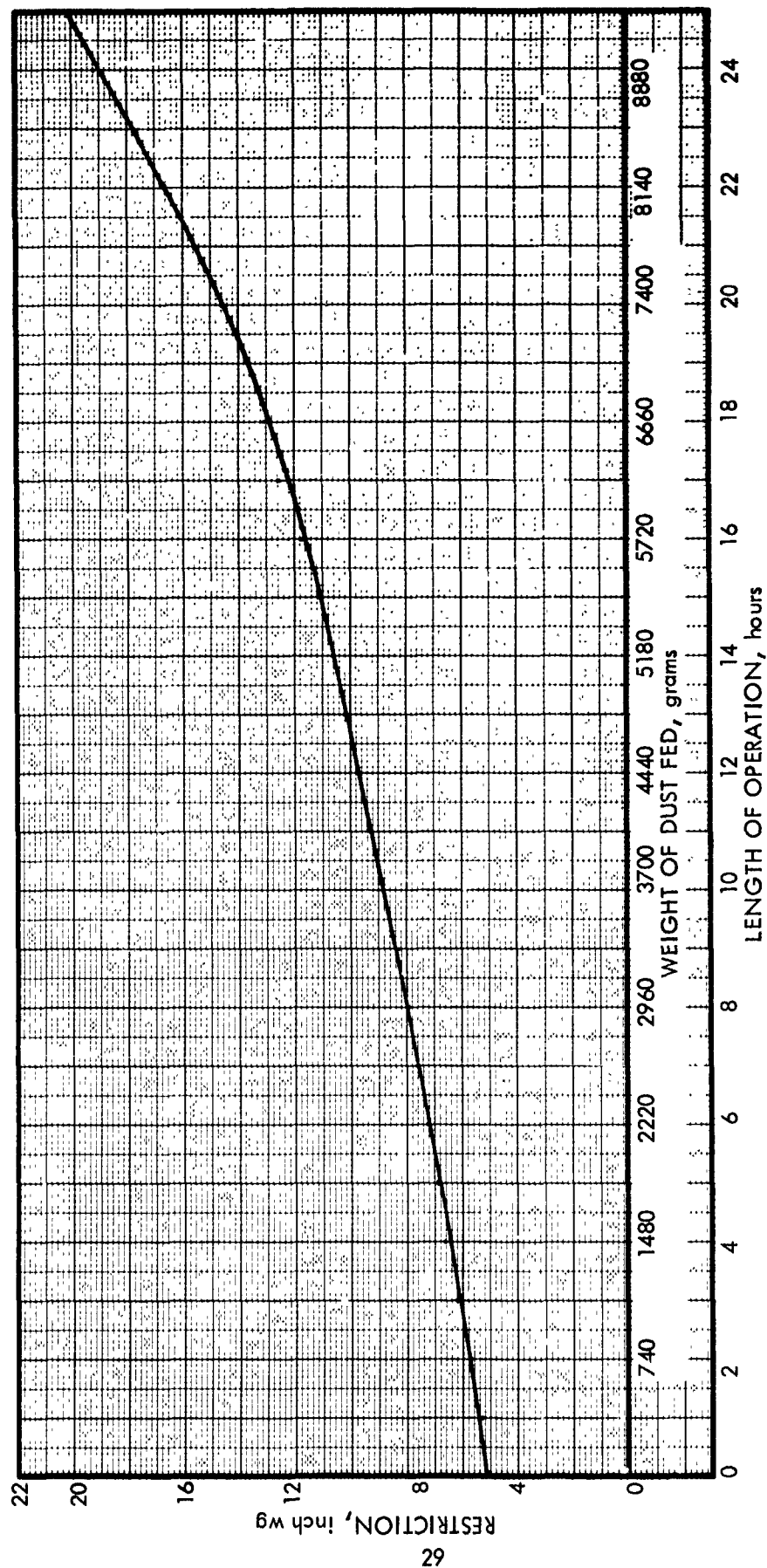


FIGURE 13. 410 CFM PROTOTYPE AIR CLEANER DUST CAPACITY WITH STANDARD AIR MANIFOLD AND DUST EXHAUSTER CUP AND BLOWER

#### 4 Restriction After Cleaning

Upon completion of the dust capacity tests and cleaning of the filter elements, each air cleaner was tested for increase in initial restriction (par 3.4.4.1 of MIL-E-46736(MO)). Table III shows that increase in initial restriction was constant for each size at 0.7 inch wg. Thus, in no case did increase in restriction exceed the 1 inch wg allowable.

#### 5 Vibration Resistance

Each of the six filter elements was subjected to vibration specified in method 201A of MIL-STD-202 except that the duration of vibration was 8 hours in the vertical axis and 4 hours in each of the horizontal axes, first at 150°F and then at 165°F. Prior agreement with the Government Technical Supervisor had established that vibration at room temperature was not required. Inspection upon completion of the tests showed no structural or assembly damage.

#### 6 Efficiency After Vibration

Efficiency tests at rated flow were performed with AC Fine Test Dust on each of the elements tested for vibration. The values obtained are presented in Table III. Reduction in efficiency ranged from 0.01 to 0.25 percentage points, however, all efficiencies were still in excess of the 99 percent minimum allowable.

#### 7 Ozone Resistance

Specific ozone resistance tests were not performed on the air cleaners since all gaskets are fabricated of materials which have, by extensive previous use in similar application proven resistance to ozone. The gaskets are natural sponge rubber with a solid neoprene dip which forms a continuous skin over the cellular sponge.

#### 8 Durability

A durability test was run on a 320 cfm filter element (P/N 11604543) per par 4.5.4.5.5 of MIL-E-46736(MO). Since all elements were of the same construction, durability test of one element should prove the entire set of six sizes. The Government Technical Supervisor concurred with this decision. The prescribed cycling procedure was repeated until a total of 50 hours of dust feeding at a dust concentration of 0.05 gm/cu ft was completed. Upon completion, the element showed no evidence of damage. Initial efficiency of the filter element measured 99.66 percent. As the test progressed, efficiency gradually increased until no penetration of AC Fine Test Dust was measurable after the final cycle.



## 9 Backfire

Backfire tests were performed, per par 4.5.4.1 of MIL-E-46736(MO), on each size element. The great majority of potential applications for the family of air cleaners will be on diesel engines, not gasoline engines. However, because the possibility of use on gas engines does exist, the backfire tests were deemed applicable.

Each size element successfully underwent backfire tests as evidenced by no visible structural damage to the filter element. Some problems were encountered in retaining the dust cup under the higher pressure blasts of air. Since the filter element and dust cup are held against the manifold by pressure of the overcenter latches only, the spring clips allowed some movement. In that the backfire test is designed to check strength of the filter element, the manifold was rigidly connected to the dust cup with tie bolts. Tests in this manner assured that each filter element received the full effect of the air pressure.

## VI DOCUMENTATION

### A DRAWINGS

Drawings of the air cleaner family evolved from initial concept layouts, through coordination drawings and finally resulted in Class I drawings on Ordnance linen. Drawing format was in accordance with MIL-D-70237 and ORDM 4-4.

A total of 123 Class I drawings were made, using a block of numbers from 11604-500 to 11604608. Parts lists accompanied each set of drawings covering a specific air cleaner configuration.

### B MONTHLY PROGRESS REPORTS

Twelve narrative reports of progress were submitted monthly throughout the contract term. These reports covered details of design, fabrication and test work as well as a current report of funds spent. The material through section V.A. of this final report essentially summarizes the monthly reports.

### C DESIGNER'S HANDBOOK

A Designer's Handbook was prepared to facilitate utilization of the family of air cleaners. This document included, in addition to overall design and operation information, specific details of dimensions, weights, predicted dust lives, predicted air restrictions, service instructions and accessory parts.

## VII CONTRACT COORDINATION

### A MEETINGS

A total of 8 meetings were held between Government and Donaldson Company personnel. The details of these are tabulated below.

<u>Date</u>	<u>Location</u>	<u>Attendees</u>	<u>Purpose</u>
17 Mar 65	USATAC	D.K. Anderson T.A. Baden T.G. Donnelly M.R. Johnson	Define approach to contract technical effort.
6 May 65	Donaldson	A.L. Jaeger	Contract Coordination
22 Jul 65	Donaldson	A.L. Jaeger	Review layout drawings, choose prototype sizes.
16, 17 Nov 65	Donaldson	V.V. Pauls	Review preparation of Class I drawings.
1 Nov 65	Donaldson	A.L. Jaeger	Review preliminary prototypes contract coordination.
20, 21 Jan 66	Donaldson	V.V. Pauls	Review Class I drawings
25 Jan 66	Donaldson	A.L. Jaeger	Contract coordination
21, 22 Mar 66	Donaldson	A.L. Jaeger V.V. Pauls	Final review of Class I drawings.

### B BIWEEKLY MEETINGS AND REPORTS

Meetings were held at Donaldson Company on a biweekly basis to summarize progress and highlight any present or potential problems. The results of these meetings were recorded and three copies were forwarded to the Technical Supervisor. By this means, much closer coordination was maintained than would have been possible through use of only formal monthly progress reports.

### C SCHEDULING

The technical effort on this contract was originally planned using PERT techniques. A PERT network was also maintained throughout the period of performance.

## VIII CONCLUSIONS

A standardized family of six air cleaners is now available for wheeled and light-tracked vehicles. The airflow ratings are 110, 250, 320, 410, 550 and 800 cfm, respectively. This new standardized line offers advantages of simplicity, installation versatility, low weight,

low cubage and long service life. Optional air manifolds and dust cups allow 18 variations of air cleaner configurations from 6 basic designs. All parts have been drawn to military Class I format.

Seven prototype models have been fabricated from these Class I drawings. Laboratory performance and structural test performed per MIL-E-46736(MO) on these prototypes have verified predicted operating and physical characteristics.

#### IX RECOMMENDATIONS

It is recommended that air cleaners from this standardized family be used, wherever feasible, to protect engines of existing and new wheeled and light-tracked military vehicles. Field test under a variety of conditions should be performed to further prove performance and durability under actual use conditions.

#### INITIAL DISTRIBUTION

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AD Accession No. Donaldson Company, Inc., Minneapolis, Minnesota DESIGN & DEVELOPMENT OF A FAMILY OF DRY-TYPE AIR CLEANERS - T. G. Donnelly Final Report, April 1966, 33 pp, 13 illus, 3 tables. Contract DA-022-AMC-2041(T) Unclassified Report This final report covers design and development of a family of dry-type engine air cleaners, ranging from 110 to 800 cfm ca- pacity, for wheeled and light-tracked vehicles. Basic consid- erations included designing the family to (1) withstand the ex- tremes encountered in military use, (2) adequately protect vehicle engine and, (3) afford sufficient installation versatility to allow widespread use. The resulting family of air cleaners utilizes interchangeable air manifolds and dust cups, allowing 18 variations from 6 basic models. Laboratory tests confirmed performance meeting re- quirements of MIL-E-46736(MO). A family of air cleaners is now available for wheeled and light- tracked vehicles and should be used wherever possible on new engine air cleaner installations to better standardize military air cleaners.	UNCLASSIFIED 1. Air Cleaners, Engine 2. Contract DA-022-AMC- 2041(T)
AD Accession No. Donaldson Company, Inc., Minneapolis, Minnesota DESIGN & DEVELOPMENT OF A FAMILY OF DRY-TYPE AIR CLEANERS - T. G. Donnelly Final Report, April 1966, 33 pp, 13 illus, 3 tables. Contract DA-022-AMC-2041(T) Unclassified Report This final report covers design and development of a family of dry-type engine air cleaners, ranging from 110 to 800 cfm ca- pacity, for wheeled and light-tracked vehicles. Basic consid- erations included designing the family to (1) withstand the ex- tremes encountered in military use, (2) adequately protect vehicle engine and, (3) afford sufficient installation versatility to allow widespread use. The resulting family of air cleaners utilizes interchangeable air manifolds and dust cups, allowing 18 variations from 6 basic models. Laboratory tests confirmed performance meeting re- quirements of MIL-E-46736(MO). A family of air cleaners is now available for wheeled and light- tracked vehicles and should be used wherever possible on new engine air cleaner installations to better standardize military air cleaners.	UNCLASSIFIED 1. Air Cleaners, Engine 2. Contract DA-022-AMC- 2041(T)

## DOCUMENT CONTROL DATA - R&amp;D

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1. ORIGINATING ACTIVITY (Corporate author) Donaldson Company Inc. Minneapolis, Minnesota		2a. REPORT SECURITY CLASSIFICATION Unclassified	
		2b. GROUP N/A	
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4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final			
5. AUTHOR(S) (Last name, first name, initial) Donnelly, T. G.			
6. REPORT DATE April 1966		7a. TOTAL NO. OF PAGES 33	7b. NO. OF REFS 0
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<p><del>This final report covers design and development of a family</del></p> <p>13. ABSTRACT of dry-type engine air cleaners, ranging from 110 to 800 cfm capacity, for wheeled and light-tracked vehicles. Basic considerations included designing the family to (1) withstand the extremes encountered in military use, (2) adequately protect vehicle engine and, (3) afford sufficient installation versatility to allow widespread use. The resulting family of air cleaners utilizes interchangeable air manifolds and dust cups, allowing 18 variations from 6 basic models. Laboratory tests confirmed performance meeting requirements of MIL-E-46736(MO). A family of air cleaners is now available for wheeled and light-tracked vehicles and should be used wherever possible on new engine air cleaner installations to better standardize military air cleaners.</p>			

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Air Cleaners Cleaners, Air Dry-Type Cleaners Interchange						

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